Fermi National Accelerator Laboratory

FERMILAB-Conf-97/145-E
CDF

Jet Fragmentation Properties at the Tevatron

Konstantin Goulianos
For the CDF Collaboration

The Rockefeller University
New York, New York 10021

Fermi National Accelerator Laboratory
P.O. Box 500, Batavia, Illinois 60510

May 1997

Published Proceedings of the *QCD and High Energy Hadronic Interactions, XXXII Rencontres de Moriond*, Les Arcs, France, March 22-29, 1997

Operated by Universities Research Association Inc. under Contract No. DE-AC02-76CH03000 with the United States Department of Energy

CDF/PUB/JET/PUBLIC/4169

RU 97/E-28

May 16, 1997

JET FRAGMENTATION PROPERTIES AT THE TEVATRON

Konstantin Goulianos

The Rockefeller University, New York, NY 10021

(The CDF Collaboration)

Presented at

"QCD and High Energy Interactions, XXXIInd Rencontres de Moriond"

Les Arcs, France, March 22-29, 1997.

ABSTRACT

Preliminary CDF results on inclusive momentum distributions of charged particles in high transverse momentum jets produced in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV at the Tevatron are presented and compared with QCD predictions based on the Modified Leading Log Approximation.

1. Introduction

Jet fragmentation is an inherently soft process that tests perturbative QCD at the limits of its applicability. In this paper, we present preliminary CDF results on inclusive momentum distributions of charged particles in high transverse momentum jets produced in $\bar{p}p$ collisions at $\sqrt{s} = 1.8$ TeV at the Tevatron. The data are found to be in good agreement with QCD calculations based on the Modified Leading Log Approximation (MLLA), confirming that the domain of perturbative QCD expands down to the scale of Λ_{QCD}.

The fragmentation process may be thought of as proceeding in two stages: an initial stage governed by perturbative QCD, followed by a stage of (phenomenological) hadronization. The boundary between these two stages is associated with a k_T cut-off scale Q_0. Perturbative calculations are valid for $Q_0 >> \Lambda_{QCD}$, where the probability for single gluon emission, $w \sim \alpha_s \ln^2(E_{jet}/Q_0)$, is small. The jet energy, E_{jet}, is defined throughout this paper as $E_{jet} \equiv M_{JJ}/2$, where M_{JJ} is the mass of the dijet system in a two-jet event. For $E_{jet} = 200$ GeV, $w \sim 1$ at $Q_0 \sim 10$ GeV. Since the transverse energy scale of hadrons in jets is well below 10 GeV, perturbative QCD based on α_s expansion cannot be used to predict jet fragmentation properties.

The double-log term in the single gluon emission probability originates from soft ($\sim dk/k$) and collinear ($\sim dk_T/k_T$) divergencies. This problem is overcome in the Leading Log Approximation [1)] (LLA), where the dominant (leading log) diagrams are summed to all orders in α_s. The task of carrying out this summation is technically challenged by the need to correctly account for the effects of color interference between diagrams. In the early 1980s, it was shown that, because of destructive interference, a secondary parton cannot be emitted at an angle exceeding that of the previous emission. This *angular ordering* was crucial to the development of the LLA. Shortly thereafter, the LLA was expanded [2–4)] to the MLLA, which includes next-to-leading log terms. Calculations in the MLLA aproach can be performed using an analytical formula describing a wide range of intra-jet features with essentially no free parameters. The results obtained from this formula are surprisingly infrared stable down to the limit $Q_0 = \Lambda_{QCD}$. Here, this limit will be referred to as Q_{eff} and will be left as a free parameter in the theory to be determined by the data.

The MLLA formula we use has the form

$$\frac{1}{N_{events}} \frac{dN_{trk}}{d\xi} = \text{Const} \cdot f_{MLLA}(Y, \xi) \tag{1}$$

$$\xi \equiv \ln \frac{1}{x}; \quad x = \frac{p_{trk}}{E_{jet}}; \quad Y = \ln \frac{E_{jet} \cdot \theta_{cone}}{Q_{eff}}; \quad E_{jet} = \frac{M_{JJ}}{2}$$

where p_{trk} is the momentum of a charged particle (track) within a cone of angle θ_{cone} with respect to the jet axis. The function f_{MLLA} is the MLLA formula for the number of final state partons per unit ξ per event (dijet) **for gluon jets**. The normalization factor "Const", which is determined by the fit to the data, is a product of three factors: Const $= H \cdot C \cdot G$. The factor H represents the ratio of the number of hadrons to the number of final partons; if hadronization is indeed equivalent to simple "dressing up" of final partons to convert them to colorless hadrons, H should be unity. The factor C represents the fraction of charged to all particles; for a final state consisting of pions, $C = 2/3$. The last factor, G, is unity for a gluon jet and 4/9 for a quark jet (4/9 is the ratio of quark to gluon color charges). Thus, the value of "Const" is expected to be $\sim 2/3$ ($\sim 8/27$) for gluon (quark) jets.

The peak position of the ξ distribution depends only on Y:

$$\xi_0 = \frac{1}{2}Y + \sqrt{cY} - c, \quad c = 0.29\,(0.32) \text{ for } n_f = 3\,(5) \tag{2}$$

The constant c (third term in Eq. 2) is not fully controlled by the MLLA, as next-to-MLLA terms may contribute at this level.

2. Data sample

The results presented here are based on a sample of events with two jets selected to have $|\eta_{jet}| < 0.9$, $|\Delta E_T|/(E_{T1} + E_{T2}) < 0.15$, $45^\circ < |\theta^*_{JJ}| < 135^\circ$ and dijet mass $72 < M_{JJ} < 740$ GeV. The events were grouped into 9 mass bins with average dijet mass

$$< M_{JJ} >= 83,\ 105,\ 135,\ 175,\ 225,\ 300,\ 390,\ 490,\ 625\ \ \mathrm{GeV}$$

and for each mass bin the charged particle ξ-distributions were studied for jet cone angles

$$\theta_{cone} = 0.168,\ 0.217,\ 0.280,\ 0.361,\ 0.466$$

The adjacent average mass values differ by a factor of ~ 1.3, which was chosen so that the difference $\delta < M_{JJ} > / < M_{JJ} >$ be larger than the resolution in the dijet mass measurement (estimated from $\Delta E_T/\Sigma E_T$ balance to be $\sim 20\%$ at $M_{JJ} \sim 80$ GeV and $\sim 8\%$ at $M_{JJ} \sim 400$ GeV). The θ_{cone} angles were also chosen to differ by a factor of ~ 1.3, so that the values of $\ln(M_{JJ} \cdot \theta_{cone})$ be approximately equally spaced for the various mass-angle combinations.

Two important corrections were applied to the data: one for tracking efficiency, which affects mainly the high dijet mass data where the particle densities are higher, and the other for the underlying event contribution to particles within the jet, which affects the high end of the ξ-distributions. Both corrections were evaluated from the data with guidance from Monte Carlo simulations.

3. Results

Figure 1 shows the ξ-distribution for data of cone angle $\theta_{cone} = 0.466$ and various mass bins, and Fig. 2 the evolution of the ξ-distribution with cone angle for the data of dijet mass 390 GeV. The data are compared with MLLA predictions. The curves should go to zero at $\xi = 0$ (energy conservation), but their exact form is not controlled by the MLLA, which was derived assuming $x << 1$. We therefore do not fit the data for $x > 0.22$ or $\xi < 1.5$. On the high-ξ end, we do not fit the data for $p_{trk} < (0.250\ \mathrm{GeV})/\theta_{cone}$, which corresponds to p_T smaller than 250 MeV ($\approx Q_{eff}$) for particles at the cone angle. Within the fit regions the data are in good agreement with the MLLA predictions.

The fit values of the normalization, "Const", seem to decrease with increasing M_{JJ} (Fig. 1). Such a decrease would be consistent with expectations based on the increase (according to HERWIG Monte Carlo simulations) of the fraction of quark jets in the data with increasing dijet mass.

Figure 3 shows the peak position versus $M_{JJ} \cdot \theta_{cone}$ (Eq. 2) for CDF data and for data from e^+e^- experiments. The MLLA fit (superimposed) is in excellent agreement with the data and yields $Q_{eff} = 234 \pm 2(stat) \pm 15(syst)$ MeV, confirming that in this approximation the domain of perturbative QCD extends down to $Q_{eff} \sim \Lambda_{QCD}$.

References

1. See review by A. Basseto, M. Ciafanoli and G. Marchesini, Phys. Rep. C100 (1983) 201.
2. A.H. Mueller, Nucl. Phys. B213 (1983)85, erratum in B241 (1984) 141.
3. Yu. Dokshitzer and S. Troyan, XIX Winter School of LNPI, Vol. 1, p. 144, Leningrad.
4. E.D. Malaza and B.R. Webber, Phys. Lett.B149 (1984) 501.

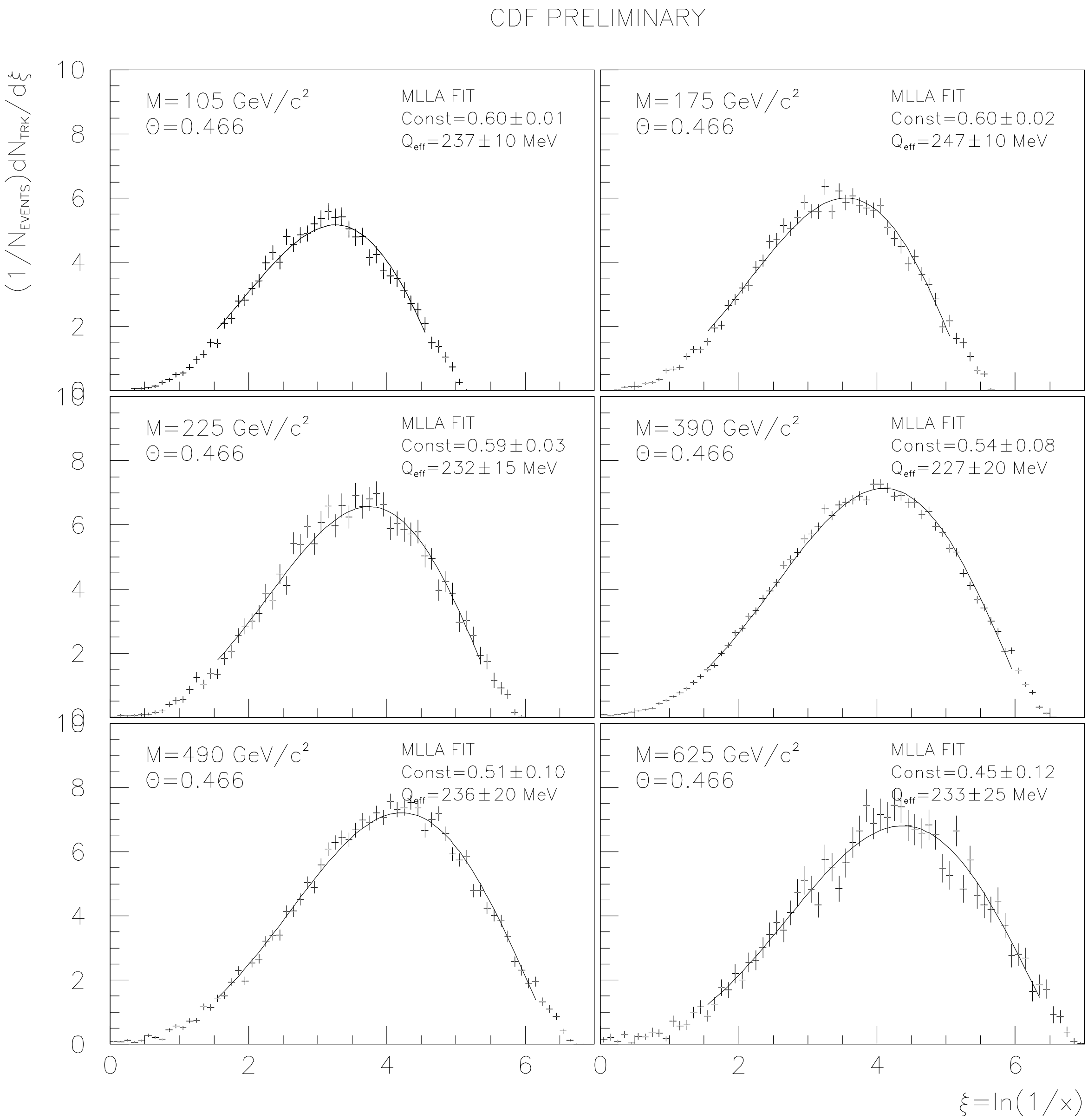

Figure 1: Inclusive momentum distributions of charged particles in jets for different dijet masses, M_{JJ}, and a fixed cone angle of $\theta_{cone} = 0.466$. The curves are MLLA fits. The fit boundaries correspond to $x = 0.22$ on the left and $x = (0.5\ \text{GeV}) \cdot \theta_{cone}/M_{JJ}$ on the right. The errors shown include systematic uncertainties.

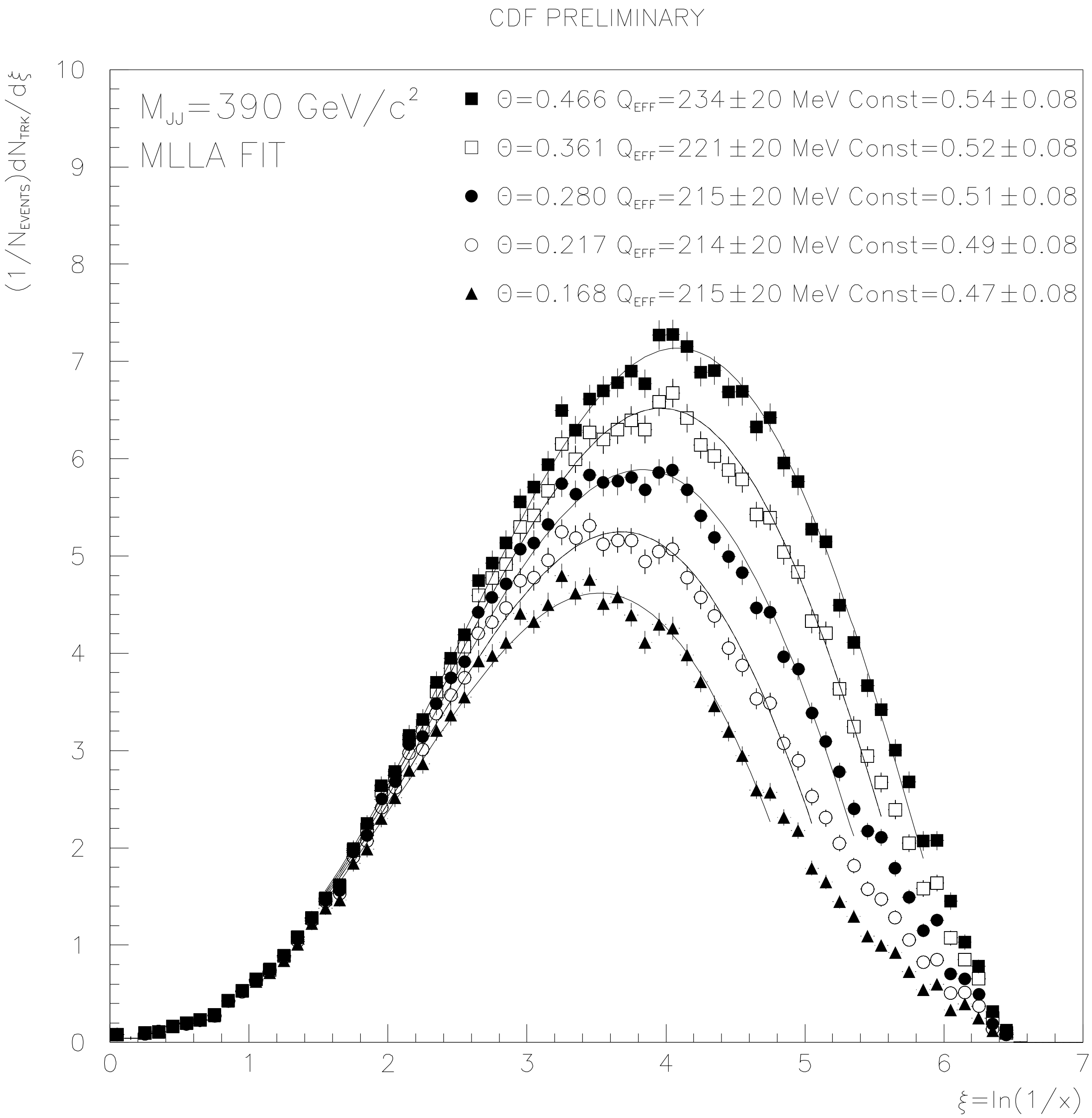

Figure 2: Evolution of the inclusive momentum distribution of charged particles in jets as a function of cone angle for a fixed dijet mass of $M_{JJ} = 390$ GeV. The curves are MLLA fits. The fit boundaries correspond to $x = 0.22$ on the left and $x = (0.5 \text{ GeV}) \cdot \theta_{cone}/M_{JJ}$ on the right. The errors shown include systematic uncertainties.

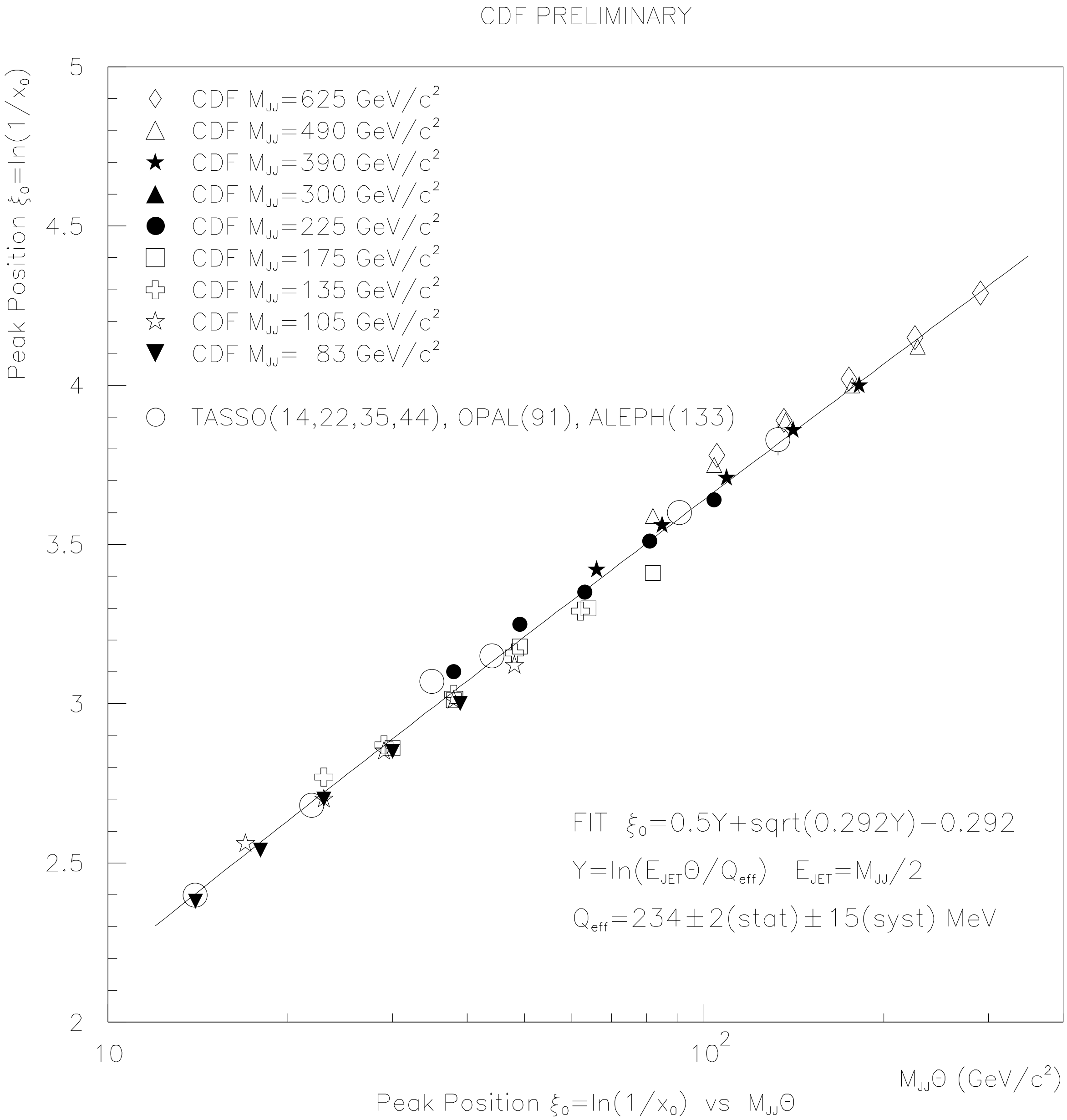

Figure 3: The peak position, $\xi_0 = \ln(1/x_0)$, of the inclusive momentum distribution of charged particles in jets as a function of $M_{JJ} \cdot \theta_{cone}$. The data points are from CDF and e^+e^- experiments. The line through the data is a MLLA fit obtained using Eq. 2 with $c = 0.292$ and Q_{eff} as a free parameter. The data confirm the predicted $M_{JJ} \cdot \theta_{cone}$ scaling. The fit yields $Q_{eff} = 234 \pm 2(stat) \pm 15(syst)$ MeV, confirming that in the MLLA the domain of perturbative QCD extends down to $Q_{eff} \sim \Lambda_{QCD}$.